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EVALUATION OF FOAMED ASPHALT ROAD BASES USING LOCAL SANDS OR INSITU SOILS

Alberta
MUNICIPAL AFFAIRS
Innovative Housing Grants Program

[redacted]

EVALUATION OF FOAMED ASPHALT ROAD BASES USING LOCAL SANDS OR INSITU SOILS

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The views and conclusions expressed and the recommendations made in this report are entirely those of the authors and should not be construed as expressing the opinions of Alberta Municipal Affairs.

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FOREWORD

The project documented in this report received funding under the Innovative Housing Grants Program of Alberta Municipal Affairs. The Innovative Housing Grants Program is intended to encourage and assist housing research and development which will reduce housing costs, improve the quality and performance of dwelling units and subdivisions, or increase the long term viability and competitiveness of Alberta's housing industry.

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As the type of project and level of resources vary from applicant to applicant, the resulting documents are also varied. Comments and suggestions on this report are welcome. Please send comments or requests for further information to:

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EXECUTIVE SUMMARY

1. Purpose of the project: The foamed asphalt process permits productions of asphalt pavement utilizing wet and marginal materials with potential significant cost savings. The purpose of the project was to research foamed asphalt to determine the feasibility of reintroducing the product into Alberta.

2. Methodology used: A review has been conducted of published literature on projects carried out in the U.S. including technology and types of materials employed and results obtained. Inspection has been made and details obtained on typical foamed asphalt projects carried out recently and at earlier dates in the U.S. The performance of existing foamed asphalt pavements, constructed in the 1960's in Alberta, has been evaluated.

   Samples of soils have been obtained from typical subdivisions in the Edmonton and Calgary areas and these soils tested in the laboratory for use in the foamed asphalt process.

   In addition, an evaluation has been conducted of existing foamed asphalt technology and studies carried out on the re-design of existing asphalt equipment to make it suitable for the foamed asphalt process.

3. The key issues raised in the work: The limiting fines content and plasticity of materials for use in the foamed asphalt process were key issues in this investigation. Other key issues were the importance

of proper control of asphalt content, moisture content and foaming characteristics of the asphalt in terms of their impact on the production of suitable foamed asphalt mix.

4. Main Findings: The investigation has shown that a wide range of fine-grained materials may be utilized in the foamed asphalt process. Proper control of asphalt content, moisture content and foaming quality of asphalt is required for satisfactory foamed asphalt product. Fine sands with fines contents of 10% to 35% passing a 80 um (#200) standard sieve size have been successfully utilized in the foamed asphalt process. Samples of insitu low plastic clay-silt soils with up to 50% passing a 80 um (#200) standard sieve size have been used in the foamed asphalt process with only a minor amount of undesirable soil-asphalt aggregation. Moreover, it was found that 5% to 10% of silty material actually increased the strength of the mix.

A comparison of construction costs for road projects using the foamed asphalt process in lieu of conventional granular base and hot mix asphalt pavement shows the following information. Road paving projects, of comparable design strength, have shown savings in the order of 20% to 35% of total construction costs by using the foamed asphalt process over conventional granular base. This saving in construction costs is largely attributable to the elminiation of heating (drying) costs for aggregate and the permissible use of a lower quality aggregate with the foamed asphalt process. In addition, costs of haul are often reduced by using a lower quality

sand material available closer to the development site.

5. Conclusions: This investigation shows that the foamed asphalt process can be applied to Alberta fine-grained sands and some fine-grained insitu soils to produce satisfactory foamed asphalt pavement mix. Laboratory design and field quality control of materials must be used to ensure satisfactory foamed asphalt product from borrow to insitu soils on a site by site basis.

1.0 INTRODUCTION

1.1 Purpose of Study

The foamed asphalt process was originally devised by Professor Ladis Csanyi of Iowa State University in 1957. The process consisted of foaming asphalt by injecting steam under pressure into a hot liquid asphalt, utilizing a particular type of nozzle. The asphalt in the foamed condition appears to possess the characteristic of having very thin films permitting it to readily mix with wet granular materials containing high percentages of fines. The foaming process was later modified by Mobil Oil of Australia which injected a small amount of cold atomized water, instead of steam, into the asphalt to produce foamed asphalt. This latter cold water process is a patented process held under the Trademark "Foamix" by Conoco Inc. Either process produces foamed asphalt of suitable quality for use.

The foamed asphalt process was used successfully in Alberta in the early nineteen sixties to produce pavements on secondary roads and asphalt stabilized base for town projects. The process was used in the U.S. at the same time and has continued to be used there on major highways, secondary roads and town paving projects. Significant cost savings were made by using the foamed asphalt process. This project involves research of foamed asphalt to determine the possibility of reintroducing it, with associated cost savings, to Alberta.

1.2 Context of Problem

Many development and project locations in Alberta are relatively short of quality granular materials for roads and pavements with resulting long and costly hauls to supply necessary materials. In many cases, marginal sands and granular materials are available at or near the specific project, which materials are suitable for use in foamed asphalt paving mixes. In addition, insitu materials, with little or no modification, in many cases could be utilized in the foamed asphalt process. The resulting cost savings to a particular development may be extremely significant. Insitu soils have reportedly been used on some foamed asphalt projects in the U.S. but no literature references on this method of application have been obtainable.

1.3 Scope and Focus of the Study

The scope of the study includes the following:

1.3.1 A review of published information on foamed asphalt in Canada and the United States with respect to performance and technology.

1.3.2 An evaluation of the performance of foamed asphalt pavement, installed in the early nineteen sixties in the Town of St. Albert.

1.3.3 An assessment of current foamed asphalt practices and technology in the United States leading to modifications to the technology for use in Alberta.

1.3.4 Site and laboratory investigations to determine the suitability of local sands and insitu soils for the foamed asphalt process in subdivisions in Calgary and Edmonton.

1.3.5 Laboratory analyses to determine optimum mix designs for foamed asphalt using local sands and insitu soils.

1.3.6 Redesign of existing asphalt mix and pavement equipment for use in the foamed asphalt process in Alberta.

The work will focus on the evaluation of existing technology, modifications to that technology for use in Alberta, site and laboratory investigations, and equipment redesign.

1.4 Organization of Research

The investigation and report has been divided into the following phases to ensure a complete and comprehensive coverage of all aspects of the project.

1.4.1 Literature Review

Relevant published information from Canada, United States, Australia and United Kingdom has been reviewed and findings detailed here under. Detailed references are listed in the attached Bibliography.

1.4.2 Performance Evaluation of Foamed Asphalt Pavements

Inspection and evaluation has been carried out on local (Town of St. Albert) foamed asphalt projects and on foamed asphalt projects in the United States to evaluate performance after a 10 to 24 year period of installation.

1.4.3 Site Investigations and Mix Designs

Investigation has been conducted on a typical subdivision in the Edmonton area and on a similar subdivision in the Calgary area. Samples of insitu soils and sand pit (borrow) materials have been tested in the laboratory for suitability to use in production of foamed asphalt mixes.

1.4.4 Equipment Evaluation and Redesign

Existing asphalt equipment has been inspected, and design modifications with cost estimates prepared to permit utilization of existing equipment in production of foamed asphalt mixes.

2.0 LITERATURE REVIEW

The literature review is divided into different applications and types of foamed asphalt usage. Applicable technical reference papers, as noted, are listed in the attached Bibliography.

2.1 Foamed Asphalt Process Technology

2.1.1 Foamed Asphalt Process Technology Using Local Sands and Aggregates

A number of laboratory investigations and mix designs on fine sands from the Edmonton and Northern Alberta area were performed by Dr. Ladis Csanyi and Curtis in the early sixties. In addition M.Sc. theses by Haas and Laplante were conducted at the University of Alberta on foamed asphalt and using local sand materials.

The above investigations (Csanyi and Curtis) utilized a fine non plastic dune type (blow) sand with 100% passing a (#10) sieve, 96 to 99% passing a # 40 sieve and 3 to 12% passing an 80 um (#200) screen. Satisfactory mix properties were obtained using a moisture content approximately 2% below optimum moisture and asphalt contents in the order of 5 to 6.5%. Investigation showed that very clean sands resulted in unsuitable asphalt mix of very low stability and poor durability.

Haas and Laplante theses at the University of Alberta on similar fine sand materials with 99% passing a # 40 sieve and 8% passing an 80 um (# 200) sieve showed the following pertinent results.

1. Foamed asphalt mixes showed higher structural strength than comparative cut back (MC3) or hot mix asphalt specimens. (Cut backs are asphalts which are liquified by blending with petroleum solvents. The MC3 grade of asphalt is liquified by blending with a solvent similar to kerosene).

2. Foamed asphalt mixes showed more uniform and continuous films of asphalt binder on the aggregate particles than the comparative cut back and hot mix asphalt mixes.

3. Foamed asphalt mixes showed loss of strength upon immersion similar to the comparative MC3 and penetration grade asphalt cement mixes. (Asphalt cement is asphalt that is refined to meet specifications for paving usage).

4. The addition of a limited amount of fines is beneficial to the cured strength of poorly graded sand foamed asphalt mixtures. (Reference Bibliography items 1 to 9 inclusive).

2.1.2 Foamed Asphalt Process Technology Using Local Aggregates

Laboratory investigations and mix designs on 19 mm (3/4") crushed road gravels were carried out on local (Calgary) materials in the early sixties. Investigations showed that a satisfactory foamed asphalt mix suitable for surface course could be produced from crushed gravel samples supplied. Crushed gravel samples with a low percentage of fines (passing # 80 um) produced foamed asphalt mixes of low stability. A mix composed of large stones only or an extremely coarse graded mix is generally unsatisfactory. Coarse rock is not coated satisfactorily by the foamed asphalt process and sufficient fines must therefore be available to form a matrix for the coarse rock. This condition can usually be overcome by blending sand with a coarse mix. (Reference Bibliography 10, 11, 12, 13).

2.2 Foamed Asphalt Process Technology From Canada, United States, Australia and United Kingdom

2.2.1 Dr. Ladis Csanyi, originator of the foamed asphalt process, reported on the effect of asphalt film thicknesses on strength and performance properties of asphalt mixtures and the ability of the foamed asphalt process to produce very thin films of asphalt. This condition of thin films permits the asphalt to more readily mix with wet granular materials containing high percentages of fines. (Reference Bibliography 14, 15, 16).

2.2.2 U.S. State and Research Agencies have reported on numerous foamed asphalt construction and research projects utilizing sands and marginal gravels. Some agencies reporting and which are referenced in the attached Bibliography include: Iowa (17), Colorado (18, 27), Montana (19, 20), Oklahoma (21), Maine (22), Indiana (23, 24, 25), Michigan (26), Virginia (27), Arizona (28), North Dakota (29) and Illinois (30).

2.2.3 The foamed asphalt process has been used successfully in the recycling of asphalt pavements (Reference Bibliography 23, 24, 25, 26). This is a very cost effective means of reconstruction of an asphalt pavement.

2.2.4 Common Findings From References A wide range of sand and marginal gravel has been used by the above States and agencies reporting on the foamed asphalt process. Extensive research into the properties of materials and resulting foamed asphalt mix has been carried out by many States and Universities involved. In general, the following pertinent findings and conclusions are common to many of the above referenced reports.

1. Aggregate Quality

A minimum of 3 to 5% passing the 80 um (# 200) sieve size is considered by some agencies (21) to be a basic requirement to get a suitable foamed asphalt mix. Other agencies (19) suggest a minimum of approximately 10% passing the 80 um (# 200) screen for suitable mix. A top limit of 30 to 40% passing the 80 um (# 200 mesh) screen has been used by some agencies (19) to produce suitable foamed asphalt mix. Many agencies require 100% of material to pass a 2.0 mm (# 10 mesh) sieve size (19).

2. Mixing Moisture Content

Most agencies have pointed out the need for mixing water of 90 to 95% of optimum moisture in the soil aggregate before the addition of the foamed asphalt (21, 19, 17). (Optimum moisture content is the water content of the soil-aggregate mixture at which maximum dry density is obtained with a particular compactive effort).

3. Asphalt Content and Type

The proper asphalt content to produce the highest stability of mix is recognized as a fundamental requirement by most reference sources. However, it is also noted by some references (19, 20, 21) that the percentage of water absorbed by compacted specimens decreased with increasing percentages of asphalt in the mix. It was also reported that absorption decreased with the use of a 200/300 penetration grade asphalt when compared to 150/200 or 85/100 penetration grade material, with comparable stability of mix being maintained. In view of the critical nature of moisture susceptibility of the foamed asphalt mix, the softer grade of asphalt may be desirable use in mixes. The penetration grade of the asphalt is a measure of the consistency of the asphalt cement as refined for road paving purposes. The higher penetration values indicating a softer consistency of the asphalt cement at normal temperatures in all instances.

4. Foaming characteristics of an asphalt are

important to produce a high quality foamed asphalt mix (19). An asphalt foaming ratio of 10 to 15 is recommended. Foaming ratio is the ratio of the maximum foam volume to the volume of asphalt remaining after the foam has settled.

5. Curing Conditions

Importance of curing conditions is recognized (19, 21). Foamed asphalt mixes tend to improve with age, traffic and temperature, which conditions contribute to the removal of moisture from the compacted mix.

3.0 PERFORMANCE EVALUATION OF EXISTING FOAMED ASPHALT PAVEMENTS

3.1 Town of St. Albert, Alberta

Foamed asphalt mix was first produced and laid as a stabilized base material on St. Albert streets in 1962. Subgrade soils in the subdivision area consisted of clayey silts of CL - ML classification and in a soft to firm condition. A fine (dune) type sand, available immediately adjacent to the town was processed in a central plant mix operation at the sand pit to produce foamed asphalt. The foamed asphalt mix was then hauled to the streets and laid with a modified asphalt paving machine. A design asphalt content of 6% was specified together with a moisture content of 6%. Original mix design gradation and strength characteristics are included in Appendix I.

The foamed asphalt mix was used as a stabilized base material on the St. Albert streets. A 150 mm (6") thickness of foamed asphalt base was used on residential streets and a 225 to 325 mm (9 to 13") thickness was used on residential collector and arterial routes. A 50 mm (2") lift of hot mix asphalt pavement was used as a wearing course over the foamed asphalt mix on the residential and a 75 to 138 mm (3 to 5.5") lift applied on collector and arterial routes.

Approximately 33,450 m^2 (40,000 sq.yds.) of foamed asphalt base was laid on the St. Albert project at street locations shown on the City map, Appendix 1-1.

3.1.1 Investigation of Foamed Asphalt Conditions and Performance in 1986

The following investigation has been carried out to determine the present condition and performance of the above foamed asphalt base laid in 1962.

3.1.2 Traffic Volumes

No traffic count data is available for the subject foamed asphalt street for the interval of 24 years since construction. It is however evident that normal traffic conditions for residential, collectors and arterial streets have existed over the years. A mixture of cars, light trucks and heavier loaded trucks have used the streets at all times. The present approximate traffic volumes from data supplied by the City of St. Albert Engineering Department are as follows:

	Street Designation	Average Daily Traffic Count (Vehicles/Day)
(a)	Residential	300 to 400 (in both directions)
(b)	Residential Collector (Cunningham Road)	1600 (in each direction)
(c)	Major Arterial (Sir Winston Churchill Avenue)	6800 (in each direction)

3.1.3 Pavement Rating & Condition

Residential Streets were rated for riding quality at 4 out of 10 at 50 km/h (30 mph) speeds. This rating system employed by many Highways and Transportation agencies assigns a rating of 10 to a top quality pavement and a rating of 1 to a pavement in extremely poor condition. The condition of pavement is determined from riding quality and visual appearance as judged by a group of experienced highways engineers or personnel. The pavement surface exhibits a lateral cracking condition with relatively fine cracks at an approximate crack spacing of 1.8 to 2.4 m (6 to 8'). Lateral cracks have been sealed by maintenance procedures. Very little longitudinal cracking is apparent. The streets have maintained a relatively good cross section with some loss of crown. Little to no settlement or pavement breaks are evident.

It is reported by St. Albert's Engineering Department that no over-lays or pavement replacements have been done on foamed asphalt residential streets. Paved streets utilizing conventional granular base or soil-cement base and asphalt pavement surfacing were compared to streets utilizing the foamed asphalt base and asphalt surfacing. Streets utilizing conventional granular base and asphalt surfacing and constructed at a comparable date have been over-laid with additional thickness of asphalt pavement. Comparable streets using soil-cement base and asphalt surfacing appear in similar condition to the foamed asphalt streets. The soil-cement based streets exhibit a slightly greater spacing of lateral cracking and a slightly rougher riding quality. Soil-cement based pavements on residential and arterial routes were rated for riding quality of 4.5 out of 10 at 50 km/h (30 mph) speeds.

The residential collector and major arterial routes, utilizing foamed asphalt, were rated for riding quality at 5 out of 10 at 50 km/h (30 mph) speeds. A longer spacing of lateral cracking appears to be evident in these routes as compared to the residential streets. This is considered to be attributable to the thicker foamed asphalt base and hot mix asphalt pavement used on these routes.

3.1.4 Benkelman Beam Load Deflection Testing

The condition and strength of the foamed asphalt pavements, relative to acceptable pavement strengths, was evaluated by means of the Benkelman Beam Deflection test. This test measures the deflection of the pavement surface beneath the dual tires of a single axle truck carrying a legal axle loading. The test is performed with a single axle loading of 8.17 tonnes (18,000 lbs) on 10:00 x 20 tires at 551.6 kPa (80 psi) pressure. Research has determined that deflections, in excess of values tabulated below, will over a period of time, cause distress and break up of the asphalt pavement.

Normally recommended acceptable values of deflection on various classes of asphalt pavements are as follows:

Class of Street or Road	Recommended Allowable Pavement Deflection (or rebound)
1. Residential	1.875 mm (.075")
2. Residential Collector	1.25 mm (.050")
3. Major Arterial	0.875 mm (.035")

A series of Benkelman deflection tests were run in the travel lanes on each street containing foamed asphalt base and average results of deflection are summarized below.

3.1.5 Summary of Benkelman Beam Deflection Results on St. Albert Foamed Asphalt Pavements

Location	Class of Street	Average Deflection		Recommended Allowable Pavement Deflection		Standard Deviation	
		(mm)	(in)	(mm)	(in)	(mm)	(in)
Gainsborough Avenue	RC**	1.00	(.040)	1.25	(.050)	4.25	(0.17)
Greenwich Crescent	R*	2.20	(.088)	1.87	(.075)	0.55	(.022)
Geneva Crescent	R	2.50	(.102)	"	"	1.35	(.054)
Gresham Blvd.	R	1.00	(.040)	"	"	0.48	(.019)
Gilmore Crescent	R	2.00	(.080)	"	"	0.83	(.030)
Bishop Street	R	1.75	(.070)	"	"	0.65	(.026)

R* - Residential
RC** - Residential Collector

Location	Class of Street	Average Deflection		Recommended Allowable Pavement Deflection		Standard Deviation	
		(mm)	(in)	(mm)	(in)	(mm)	(in)
Springfield Crescent	R*	5.12	(.205)	1.87	(.075)	0.93	(.037)
Seymour Crescent	R	3.28	(.131)	"	"	0.78	(.031)
Swallow Crescent	R	3.40	(.137)	"	"	0.85	(.034)
Salisbury Avenue	R	2.25	(.090)	"	"	0.85	(.034)
Stanley Drive	R	4.20	(.168)	"	"	1.20	(.048)
Cunningham Road	RC**	1.75	(.070)	1.25	(.050)	0.65	(.026)
Sir Winston Churchill Dr.	MA	1.08	(.043)	.876	(.035)	0.43	(.017)

R* - Residential
RC** - Residential Collector
MA - Major Arterial

The above data indicates that the majority of the streets in the investigation are in a weak condition and would require maintenance in the form of pavement overlay to bring them up to the minimum deflection value of high quality pavements. There has, however, reportedly been no overlay or strengthening applied to these streets in the past 24 years and the streets are still giving relatively good performance after this period of use. This would compare to normal maintenance on residential streets after a period of 12 to 15 years.

3.1.6 Quality of Foamed Asphalt Base From Core Data

A series of 32 core samples were taken at representative locations over the total length of foamed asphalt base in the St. Albert streets. These cores were taken to investigate the quality of the foamed asphalt mix after the 24 year period of installation and to determine the type and condition of the underlying subgrade soil. A summary of results is as follows. Detailed test data is included in Appendix 2.

Visual inspection of cores showed the foamed asphalt base to be in sound condition throughout with no evidence of deterioration or degradation. Investigation showed the asphalt content of the foamed asphalt mix to vary from 5.4% to 8.6% with an average of 7.14% for 9 core samples tested. This compares to the specified mix design asphalt content of 6%. This higher average asphalt content does not appear to have appreciably altered the performance of the foamed asphalt base.

It is considered that the high asphalt content of the foamed asphalt base has been beneficial in preventing water from penetrating the base material and causing loss of strength and deterioration in the foamed asphalt base. The high asphalt content of the foamed asphalt base appears to have prevented drying and extensive cracking of the base as would normally occur in a conventional asphalt stabilized base or asphalt pavement after 24 year period of use.

Screen analysis on core samples of extracted foamed asphalt showed the fine sand material to compare very closely to the original mix design values of the fine sand to be utilized for the project. Detailed test data is included in Appendix I.

3.1.7 Conclusion

(1) The above investigation shows that the foamed asphalt mix, utilizing fine dune sand, has performed extremely well on the St. Albert streets project.

(2) Investigation shows that the street pavements, after 24 years of service, require strengthening by pavement over-lay in most cases to reinstate the pavements to normally accepted standards.

(3) The investigation has shown that asphalt content of mix varied appreciably during construction. It is considered that better control will produce a higher quality of foamed asphalt mix with correspondingly better performance.

(4) The investigation has verified that the foamed asphalt process can be beneficial

in utilizing low grade and marginal sands to produce asphaltic mix capable of at least 24 years of acceptable performance.

3.2 Performance Evaluation of Existing Foamed Asphalt Pavements in U.S.A.

A large number of foamed asphalt projects have been carried out in the U.S.A. over the past 25 years. Information and detail on some of the more pertinent projects are included herewith.

3.2.1 Montana Department of Highways Foamix (Foamed Asphalt) Base Project, Lodge Grass to Wyoming Border

This project, constructed in 1985, consisted of 37.8 km (22.7 mi) of 4 lane highway and 2.3 km (1.4 mi) of 2 lane highway for a total equivalent of 78 km (46.8 mi) of 2 lane highway in southern Montana. The project is located on Interstate Highway No. 90 between Lodge Grass, Montana and the Wyoming border.

The above Foamix base project is reported, as of this date, to be the largest foamed asphalt project in the world. The foamed asphalt mix was used to replace full depth asphaltic concrete on the above project. The resultant saving due to elimination of aggregate hauling and heating costs was reported to be $4,000,000.00. The total cost of the interstate highway paving project was approximately $14,000,000.00 with a net saving of approximately 29% of total cost achieved by use of the foamed asphalt process on the project.

3.2.2 Details of Foamix (Foamed Asphalt) Mix and Application

Foamed asphalt on the above project was produced by the Foamix (1) process. The Foamix process produces foamed asphalt by injecting 1.5 to 2.5% cold atomized water instead of steam into hot asphalt. Either process produces satisfactory foamed asphalt but the Foamix (1) process is considered to be more readily adaptable to field operations and to permit easier control of temperatures, pressure and asphalt content.

(1) Foamix is a trademark of Conoco Inc.

The cross-section of the interstate highway consisted of a 600 mm (2 ft) compacted sand subbase, two 112.5 mm (4.5 in) lifts of foamed asphalt, 100 mm (4 in) thickness of asphaltic plant mix surfacing and 19 mm (3/4 in) of open graded friction course (seal coat).

A silty sand was used in production of the Foamix foamed asphalt. The specified gradation of the silty sand is as follows:

Percentage by weight Passing Square Mesh Sieves, Montana Test Method MT - 202.

Sieve Size	Percent Passing
No. 4	100
No. 200	10 - 30

Soil classification A-2-4(0) (nonplastic).

Water was added to the silty sand to bring it to 90% of optimum moisture prior to mixing the foamed asphalt. An asphalt content of 6.0 to 6.25% (basis dry weight of sand) was used in the foamed asphalt mix. Satisfactory stability of mix was obtained at the moisture conditions and asphalt contents noted. Tests were carried out on different asphalts to ensure the asphalt had proper foaming ratio qualities prior to acceptance on the project. Results of foaming ratio tests showed that the harder grade asphalts did not foam as readily as the 120/150 penetration asphalt. A 2.5% water-asphalt weight ratio was used in all foaming asphalt.

Foamed asphalt was produced for the above project in central mix plants converted from asphalt or cement treated base usage. The mix was hauled to the road in trucks, spread to required thickness by blade and compacted with rubber tire rollers to the minimum of 95% of corresponding Marshall density.

3.2.3 Quality and Condition of Foamed Asphalt Base

No maintenance has been required on the above foamed asphalt project. No cracking or deterioration of mat is evident. The 4 lane interstate highway is carrying a traffic volume of 2300 Average Daily Traffic (ADT) with 20% heavy truck traffic. Freeze-thaw tests carried out during mix designs showed that no detrimental effects should occur to the foamed asphalt base from adverse weather conditions on the project.

The Foamix is expected to provide excellent strength and durability. Road Rater deflection testing by means of application of a dynamic load to the road surface has indicated some marginal areas in the foamed asphalt. However, it is considered that these readings will be improved as the foamed asphalt mix gains additional strength with curing.

3.3 Performance Evaluation of Existing Foamed Asphalt Base in North Dakota, U.S.A.

This project, constructed in 1979, consisted of a 10 km (6 mi) section of secondary highway No. 1804, with a 9.75 m (32 ft) wide pavement surface, immediately south of Bismark, N.D. Foamed asphalt on the above project was produced by the Foamix process. A 19 mm (3/4") road gravel, high in fines content, was used in production of the foamed asphalt. An asphalt content of 5% with 2% water-asphalt ratio was used in foaming of all asphalt.

The cross-section of the roadway consisted of a 150 mm (6") thickness of foamed asphalt base laid and compacted on a prepared silty and sandy clay (CL) type subgrade. A chip seal surfacing was applied as a wearing course on the project.

Foamed asphalt production was commenced initially with a travel plant. This procedure proved unsatisfactory and foamed asphalt for the balance of the project was produced at a central mix plant, converted to the foamed asphalt process, and located in the gravel pit for the project.

The gravel material utilized in foamed asphalt production was brought to approximately 90% of optimum moisture content prior to mixing the foamed asphalt.

Foamed asphalt mix was hauled to the road, laid to grade with blades and compacted with steel and rubber tire rollers.

Relatively light traffic has used the above highway since construction with an estimated 300 vehicles/day traffic count being obtained.

The foamed asphalt base with chip seal section of highway is performing satisfactorily with only minimal maintenance required over the 8 year period since construction. No lateral cracking or deterioration of foamed asphalt is evident.

3.4 Performance Evaluation of Existing Foamed Asphalt Base in Pueblo West, Colorado

Foamed asphalt base has been used each year since 1980 on roads within the Pueblo West housing development encompassing some 46 square miles of land. The development contains some 330 miles of streets which are progressively being paved with foamed asphalt base.

A crushed gravel with 100% passing a 9 mm (3/8") screen and up to 14% passing a # 80 um (# 200) screen has reportedly been used in the production of foamed asphalt. Asphalt content and moisture content of the aggregate was controlled according to mix design. Foamed asphalt material was produced in a central plant in an existing gravel pit. This is a conventional asphalt plant converted to the foamed asphalt process.

Material is hauled to the road and laid with a conventional asphalt paver. Compaction is obtained with steel and rubber tire rollers. Foamed asphalt mix was laid in a 125 mm (5") lift, compacted and an asphalt fog coat sealer applied. Pavements have been in use since 1980 and are performing satisfactorily.

4.0 SITE INVESTIGATIONS AND MIX DESIGNS

Site and laboratory investigations have been carried out in subdivisions in Edmonton and Calgary to determine the suitability of local sands and insitu soils for use in the foamed asphalt process. The program has included field sampling, classification and laboratory testing of representative samples of material to determine the properties of the materials and their general suitability for use in the foamed asphalt process. Laboratory foamed asphalt mix designs have been carried out on representative samples of materials from each site and results are detailed below.

4.1 Edmonton Subdivision Site - Insitu Soils

A typical subdivision site in North West Edmonton at 45th Avenue and River Valley Road (S.E. 1/4 - Sec.18 - Twp 52 - Rge 25 - W4M) was selected to obtain samples of insitu soil for testing and evaluation.

The above site was chosen for investigation in view of its close proximity to developed areas in the City of Edmonton and hence its early development potential. The foamed asphalt process could possibly have early application to such development area.

The sampled material was classified visually in the field and sealed samples were taken to the Curtis Engineering Associates Ltd. laboratory for detailed testing.

4.1.1 Laboratory Investigation

Testing showed the insitu soil material over the above location to range from inorganic silts and clayey silts of low plasticity to small areas of inorganic clays of high plasticity.

Laboratory gradation tests showed materials to consist of from 38% to 82% of silts and sand sizes plus 18% to 62% clay sizes with an average condition of 61% silt and sand sizes plus 39% clay sizes. Detailed test data is attached in Appendix II.

The Plasticity Index (P.I.) of the insitu soil ranged from 0 to 34.9% with an average P.I. of 16.6%.

4.1.2 Foamed Asphalt Mix Designs and Results

Foamed asphalt mix designs were carried out on a representative mixture of samples, taken for a depth of 300 mm (12") below topsoil at each sampling location, over the total site area. Water was added to the soil, prior to test, to bring the material to a moisture content of approximately 90% of Standard Optimum moisture content.

Trial batches of soil at three different asphalt contents were next stabilized by means of a twin shaft laboratory pugmill mixer equipped for the foamed asphalt process. Asphalt of 150/200 penetration grade was used in all foamed asphalt mixes. Prior to use in all foamed asphalt mixes, the liquid asphalt was tested to verify that it would exhibit a minimum Foaming Ratio of 10:1.

After mixing, Marshall stability specimens of the foamed asphalt mix were prepared by using the standard Marshall procedure of 50 blows applied on each side of the test specimen. The test specimens were next cured at $60^{o}C$ ($140^{o}F$) for 3 day and 7 day periods and tested for strength (stability) and durability characteristics. Results of tests are shown below and detailed test results are included in Appendix II, herewith.

4.1.3 Results of Tests on Foamed Asphalt Using Insitu Soils

Laboratory tests showed that foamed asphalt mix can be produced utilizing the insitu material at an asphalt content of 6.5% and a moisture content near 90% of the optimum moisture content for the material. The foamed asphalt mix exhibits high stabilities in the order of 30,000 to 40,000 newtons (7,000 to 9,000 lbs.) in the dry state and a stability of 1,800 to 2,200 newtons (400 to 500 lbs.) in the soaked test condition. Samples of the foamed asphalt mix withstood a minimum of 6 freeze-thaw cycles in all cases, indicating a relatively high resistance to freeze-thaw action.

4.2 Typical Edmonton Sand

A typical Edmonton sand was investigated to determine its suitability for use in the foamed asphalt process. Material was obtained from a sand pit site in the north west Edmonton area located at S.W. 1/4, Sec. 18 - 52 - 25 - W4M. The local sand deposit consists of a fine dune type sand, of common occurrence in the Edmonton area and in many other areas of Alberta. A total of 10 sand samples were taken at representative locations and depths over the total area of the sand deposit and one combined sample taken for testing. This sample was tested in the laboratory for gradation, plasticity, Standard Proctor, specific gravity and absorption characteristics. The material was then tested in the foamed asphalt process. Results as detailed below have been obtained and detailed test data is included in Appendix II herewith.

4.2.1 Laboratory Investigation

Sand Gradation Characteristics

The sand is a very fine, non plastic, sand with 100% passing a 630 um (#60) screen and approximately 4 to 8% passing an 80 um (#200) screen.

Standard Proctor Data

A Standard Proctor compaction test on an average sand material from the site showed a Proctor density of 1678 kg/m^3 (104.7 psf) at 10 % optimum moisture content.

Specific Gravity and Absorption Properties

The specific gravity of the average sand sample was 2.55 and the water absorption was 1.0%.

4.2.2 Foamed Asphalt Mixes Using Edmonton Sand

Foamed asphalt mixes of the Edmonton sand were prepared utilizing 150/200 grade asphalt at three different asphalt contents and with the sand at a moisture content of approximately 90% of optimum moisture. Standard Marshall stability specimens were formed and cured for 3 day and 7 day periods at a temperature of 60°C

(140°F). Specimens were then tested for stability in the dry and soaked condition. Other specimens were subjected to freeze-thaw durability tests.

A suitable foamed asphalt mix was produced utilizing an asphalt content of 5.5% and with the fine sand at a moisture content slightly above 90% of optimum moisture for the material. The foamed asphalt mix exhibited high stabilities in the order of 15,000 newtons (3,370 lbs.) in the dry state and a stability of 2,250 newtons (506 lbs.) in the soaked test condition. The foamed asphalt - sand mix was relatively tender and susceptible to loss of strength when immersed in water. This was considered to be due to the clean and fine nature of the non plastic sand.

A second test series using 15% of the insitu Edmonton soil (silty clay) from 4.1.2, above, mixed with this fine sand material was carried out. This now produced a fine (dirty) sand with approximately 15.5% passing a 80 um (#200) screen size. Foamed asphalt mix produced with this blended material at an asphalt content of 5.5% and at a moisture content of 90% of optimum moisture now showed high dry stabilities and an average stability of 4,120 newtons (925 lbs.) in the soaked test condition. Test specimens in all cases withstood a minimum of 6 cycles of freeze-thaw. Detailed test data is included in Appendix II.

The addition of silty clay to such a fine sand material produces a foamed asphalt mix of much higher stability and superior durability characteristics. Such addition of silty clay to the mix could be readily accomplished and at minimum expense on field projects.

4.3 Calgary Subdivision Site - Insitu Soils

A typical 320 acre subdivision site in north east Calgary at 32nd Avenue and 68th Street N.E. (Burlington Subdivision) was selected to obtain samples of insitu soil for testing. The insitu soil in this location is representative of many areas in southern Alberta. Samples of insitu soil were taken from 8 representative locations over the subdivision area for a depth of 300 mm (12") below topsoil and a combined mixture used in laboratory tests.

4.3.1 Laboratory Investigation

The Calgary soil was classified as an inorganic silty clay of low to medium plasticity, being a CL type soil in the Unified soil classification system.

Laboratory testing of soil samples showed the material to have a plasticity index (P.I.) range from 5.8% to 24.2% with an average of 16.8%. Gradation tests showed the material to have an average of 69% silt and sand sizes plus 31% clay sizes. A Standard Proctor compaction test on combined samples from the project showed a Proctor density of 1750 kg/m^3 (109.2 lbs/ft^3) at an optimum moisture content of 17.5%. Detailed test data is shown in Appendix 2.

4.3.2 Foamed Asphalt Mixes Using Calgary Insitu Soil

Foamed asphalt mixes were prepared at three different asphalt contents and at a moisture content of 90% of optimum moisture for the material. Asphalt of 150/200 penetration grade was used throughout. Standard Marshall stability specimens were formed and cured for 3 and 7 day periods at 60°C (140°F). Specimens were tested in the dry and soaked test condition and other specimens were subjected to freeze-thaw durability tests.

Satisfactory foamed asphalt mix was produced at an asphalt content of 6.5% and with material at 90% of optimum moisture content. The foamed asphalt mix showed high stabilities of 29,000 newtons (6,500 lbs.) in the dry state and stabilities of 8,186 newtons (1,840 lbs.) in the soaked test condition. Test specimens withstood a minimum of 6 freeze-thaw cycles in durability testing. Detailed test data is included in Appendix 2.

4.4 Typical Calgary Area Fine Sands

A typical fine sand from an area approximately 59 km (35 mi) North East of Calgary, near Beiseker was tested for suitability in the foamed asphalt process. This sand material is representative of sand materials available in many areas north east and south east of Calgary in southern Alberta.

4.4.1 Laboratory Investigation

Laboratory tests showed this material to consist of a non plastic fine sand with 100%

passing a 2.5 mm size and 7.8% passing an 80 um (#200) sieve size. The material had a Standard Proctor density of 1719 kg/m^3 (107.3 lbs/ft^3) at an optimum moisture content of 13.3%.

4.4.2 Foamed Asphalt Mixes Using Calgary Area Fine Sands

Foamed asphalt mixes, utilizing the Calgary fine sand, were prepared at three different asphalt contents and with sand at a moisture content near 90% of optimum moisture. Asphalt of 150/200 penetration asphalt was used in mixes. Standard Marshall stability specimens were formed and cured for 3 and 7 day periods at a temperature of 60°C (140°F). Specimens were tested in the dry and soaked condition and other specimens were subjected to freeze-thaw durability tests.

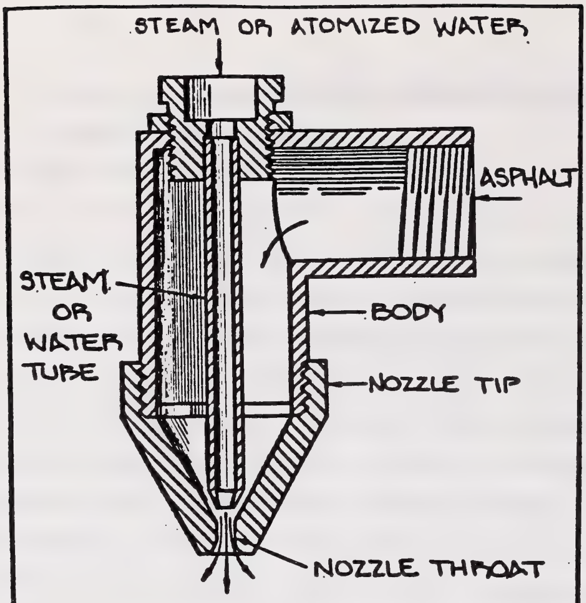
Foamed asphalt mix produced at an asphalt content of 6.5% showed high stabilities of 18,000 newtons (4,000 lbs.) in the dry condition and 1,674 newtons (376 lbs.) in the soaked test condition.

A second test series was carried out where 10% silty clay from the Calgary insitu soil site was added to the fine sand material. The resulting mixed material showed a percentage of approximately 15% passing an 80 um (#200) screen. Foamed asphalt mix produced with this blended material at an asphalt content of 6.0% showed high dry stabilities and an average stability of 4,630 newtons (1,040 lbs.) in the soaked test condition. This fine silty sand with the 10% silty clay added could readily be used to produce satisfactory mixes of foamed asphalt material.

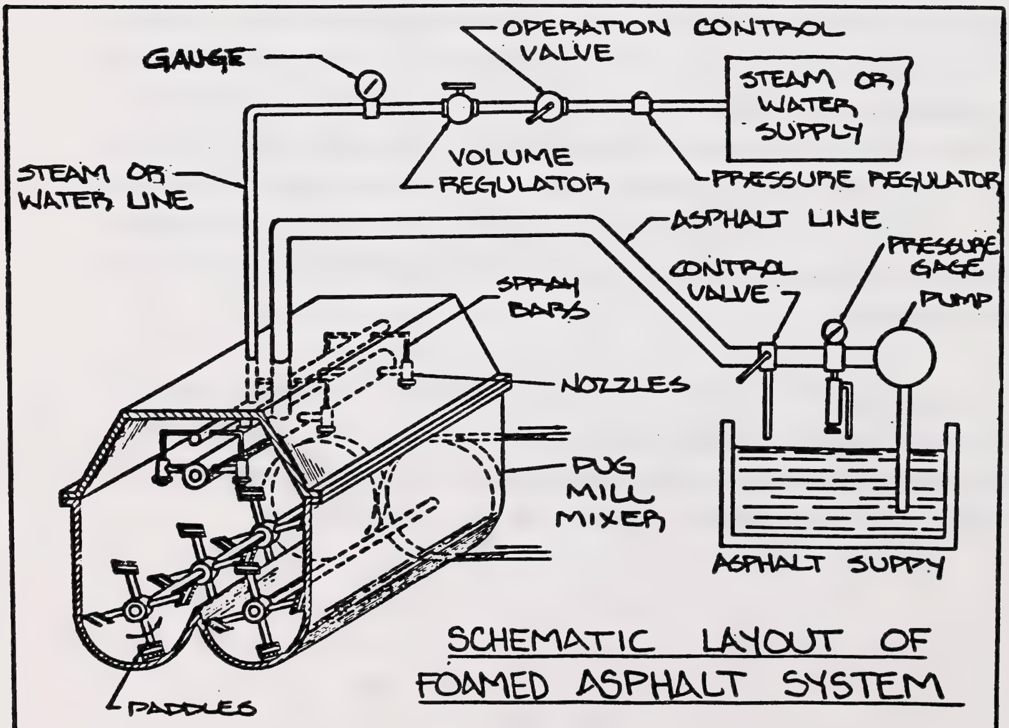
5.0 EQUIPMENT EVALUATION AND REDESIGN

Conventional asphalt plants can readily be adapted to the foamed asphalt process by installation of foaming nozzles in the pugmill mixing chamber. The layout and number of nozzles required will vary for a particular plant depending upon the size and configuration of pugmill and the production speed. The necessary design layout for conversion of a particular asphalt plant can readily be prepared by engineers and/or equipment manufacturers experienced in the foamed asphalt process. The normal cost of conversion of a central mix type asphalt plant to the foamed asphalt process is in the order of \$ 7,000 - \$ 10,000 for foaming nozzles and ancillary equipment. Some extra costs would be incurred for a steam unit or air equipment for production of atomized water as required in the foaming process. Detailed costs could be provided for a particular type of asphalt plant, as required. Other conventional equipment such as rollers, spreaders, blades, hoppers, conveyors, etc. can be applied to the production and laying of the foamed asphalt mix. Complex asphalt batch plants can be used by bypassing the aggregate drying and hot storage bins. Conversion of conventional road mix travel plants can readily be made, as for stationary plants, by installation of the foamed asphalt nozzles and support system.

A schematic layout of the typical Foamed Asphalt System and Foaming Nozzle is shown on Page 34. This basic system can be adapted and modified to suit the particular size and style of asphalt plant to be utilized.



CROSS SECTION OF FOAMED ASPHALT NOZZLE



SCHEMATIC LAYOUT OF FOAMED ASPHALT SYSTEM

Practice in the industry has been to convert existing asphalt plants to the foamed asphalt system rather than manufacture new plants, due to simplicity of conversion and economy to be effected. Continuous mix type asphalt plants of 100 tonnes per hour to 800 tonnes per hour capacity have been successfully converted to the foamed asphalt process on many U.S. and Canadian projects. In addition, many Cement Treated Base (CTB) continuous mix plants have been converted to the foamed asphalt process. Similarly CTB road mix plants can be converted to the foamed asphalt process.

The foamed asphalt process normally requires the addition of water to the sand material prior to injecting and mixing the foamed asphalt. This is accomplished by adding water to the material prior to coming to the plant, on the conveyor belt as material is elevated to the pugmill or at the input end of the pugmill. This first method of mixing water into the material prior to plant access is the most desirable. The latter method, which is also very effectively used, involves installation of water nozzles at the input end of the pugmill compartment and injecting and mixing the required water into the material immediately prior to injecting and mixing the foamed asphalt.

Conventional placing equipment such as pavers, low cost spreaders or blades can be used to place the mix. Compaction of the mix is readily attained with conventional vibratory or non vibratory steel or rubber tire compaction equipment.

6.0 CONCLUSIONS

Investigation has shown the following pertinent points and considerations.

(1) Satisfactory foamed asphalt mix has been produced in this study using clean and fine grained dune type sands from the Edmonton and Calgary areas of Alberta. These fine sand mixes exhibit high stabilities but sensitivity to water immersion if the percentage of fines of 80 um (-200) size is appreciably below 10%. However addition of fines (clay) to bring the fines content to the 15% to 20% produces a mix with stabilities comparable to acceptable grade of hot mix asphalt pavement and with satisfactory durability.

(2) Foamed asphalt mixes have been produced utilizing insitu low to medium plastic soils from the Edmonton and Calgary areas. These mixes exhibited adequate stability and durability in freeze-thaw testing procedures to indicate their acceptability for use in stabilized base work.

(3) The moisture content of the material prior to adding foamed asphalt appears to be the most important factor in the foamed asphalt mix design. Moisture contents in the order of 90% of optimum moisture content are desirable. The correct moisture content facilitates the best possible dispersion of asphalt throughout the mix which in turn produces ease of compaction and maximum stability and durability characteristics of the mix.

(4) Asphalt contents from 5% to 7% (by dry weight) have

been used to produce satisfactory foamed asphalts with the materials investigated in this study.

(5) The foamed asphalt process is considered to be quite economical in many projects and developments. Use of local materials and elimination of costly haulage will prove to be most economical for many projects.

(6) A comparative cost study between a conventional gravel base and hot mix asphalt pavement and a foamed asphalt base of comparable strength and using identical haul distances showed the foamed asphalt system to be in the order of 82% of the cost of the conventional gravel base system. This comparison utilized mixing costs which would be used in existing soil-cement projects.

A comparison of cost of foamed asphalt to soil-cement bases and utilizing fine sands as used in the above study indicates the following:

1. Cost of asphalt (5.5%) and asphalt at $ 200.00/tonne = $ 11.00/tonne.

2. Cost of cement (9.5% estimated) and cement at $ 120.00/tonne = $ 10.80/tonne.

3. Cost of mixing the materials would be comparable in each case.

The two processes are indicated to be very competitive if used for the aforenoted fine sand materials. Insitu materials or materials with a higher percentage of fines (15% to 20%) could not be used with the soil-cement process whereas the foamed asphalt process could be readily used with such materials.

The estimated savings in paving costs for streets in a conventional subdivision of 250 lot size that may be effected by using the foamed asphalt process in lieu of conventional granular base and asphalt pavement surfacing are as follows.

The total cost of street construction with conventional granular base and asphalt pavement for the 250 lot subdivision at a major Alberta city location is estimated at $ 290,000.00. Savings to be effected by using the foamed asphalt process are estimated to be in the order of $ 35,000.00 to $ 60,000.00 depending upon actual haul distances and materials sources available.

The above investigation shows that the foamed asphalt process can be readily used with fine sands and some insitu soils in Alberta to produce satisfactory asphalt base and pavement materials. In addition, performance history of the City of St. Albert foamed asphalt base verifies the suitability of the process for use with Alberta fine sands. Use of local materials with the foamed asphalt process to produce pavement and base with elimination of costly haulage will prove to be most economical.

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** Transportation Research Boards. Washington, D.C.

Report Title	Author & Date	Location of Report	Remarks
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APPENDIX I

TOWN OF ST. ALBERT

TEST DATA ON EXISTING

FOAMED ASPHALT PAVEMENTS

APPENDIX I

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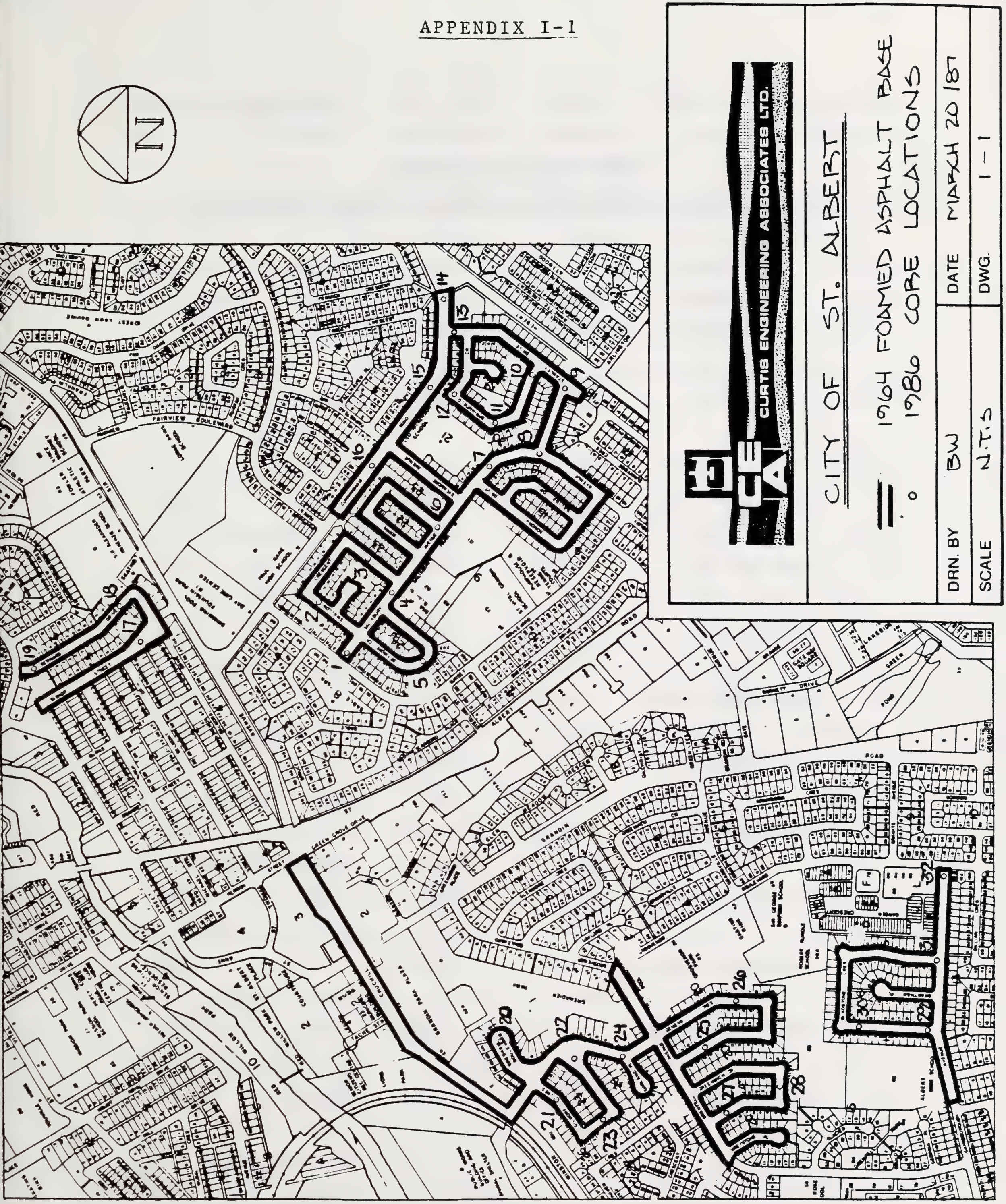
N
CURTIS ENGINEERING ASSOCIATES LTD.
CEA
CITY OF ST. ALBERT
═ 1964 FOAMED ASPHALT BASE
○ 1986 CORE LOCATIONS
DRN. BY BW
DATE MARCH 20/87
SCALE N.T.S
DWG. I-1
FAIRVIEW BOULEVARD
ALBERT
GRANDIN
GREEN GROVE DRIVE
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TOWN OF ST. ALBERT
DATA ON CORES TAKEN FROM FOAMED ASPHALT PAVEMENTS

CORE NO.	LOCATION & STREET CLASS	HOT MIX PAVEMENT THICKNESS (mm)	FOAMED ASPHALT PAVEMENT THICKNESS (mm)	SUBGRADE TYPE (Unified Class'n. system)	SUBGRADE STRENGTH (kpa)
1	Salisbury Ave. *	62.5	162.5	GP	192
2	Swallow Cr. *	62.5	162.5	ML	72
3	Swallow Cr. *	62.5	237.5	ML	216
4	Salisbury Ave. *	62.5	187.5	ML	120
5	Seymore Cr. *	62.5	162.5	ML	144
6	Salisbury Ave. *	62.5	162.5	ML	144
7	Salisbury Ave. *	150	150	ML	240
8	Salisbury Ave. *	87.5	237.5	ML	144
9	Stanley Drive *	112.5	112.5	ML	144
10	Springfield Cr. *	75	225	ML/CL	144

* - Residential

CORE NO.	LOCATION & STREET CLASS	HOT MIX PAVEMENT THICKNESS (mm)	FOAMED ASPHALT PAVEMENT THICKNESS (mm)	SUBGRADE TYPE (Unified Class'n. system)	SUBGRADE STRENGTH (kpa)
11	Springfield Cr. *	100	225	ML/CL	144
12	Springfield Cr. *	100	200	CL	144
13	Stanley Drive *	125	300	ML/CL	133
14	Cunningham Rd. **	137	325	ML	96
15	Cunningham Rd. **	112	325	ML	120
16	Cunningham Rd. **	137	375	ML	192
17	Bishop Street *	125	225	ML	216
18	Bernard Drive *	100	125	ML	200
19	Bernard Drive *	100	100	ML/CL	240
20	Greshnor Blvd. *	100	200	ML/CL	144
21	Gilmor Cres. *	75	200	ML/CL	240
22	Gilmor Cres. *	62.5	200	ML	144

* - Residential

** - Residential Collector

CORE NO.	LOCATION & STREET CLASS	HOT MIX PAVEMENT THICKNESS	FOAMED ASPHALT PAVEMENT THICKNESS	SUBGRADE TYPE	SUBGRADE STRENGTH
		(mm)	(mm)	(Unified Class'n. system)	(kpa)
23	Gilmore Cres. *	62.5	125	ML	385
24	Garland Place *	75	150	ML	160
25	Geneva Cres. *	75	150	ML	480
26	Geneva Cres. *	62.5	150	ML	144
27	Greewich Cr. *	37	150	ML/CL	480
28	Greenwich Cr. *	37	150	ML	192
29	Gladstone Cr. *	37	150	ML	480
30	Gladstone Cr. *	37	150	ML	480
31	Gainsborough Ave.- *	125	225	ML	240
32	Gainsborough Ave.- *	125	225	ML	240

* - Residential

TOWN OF ST. ALBERT

DATA ON CORES TAKEN FROM FOAMED ASPHALT PAVEMENTS

CORE NO.	LOCATION	FOAMED ASPHALT THICKNESS (mm)	% ASPHALT (By Weight of Dry Sand)
4	Salisbury Ave. *	162.5	5.8%
12	Springfield Cr. *	200	5.4%
15	Cunningham Rd. **	325	6.3%
17	Bishop Street *	225	8.7%
20	Greshnor Blvd. *	200	7.4%
22	Gilmore Cres. *	200	8.6%
25	Geneva Cres. *	150	5.9%
31	Gainsborough Ave. **	225	7.9%

* - Residential

** - Residential Collector

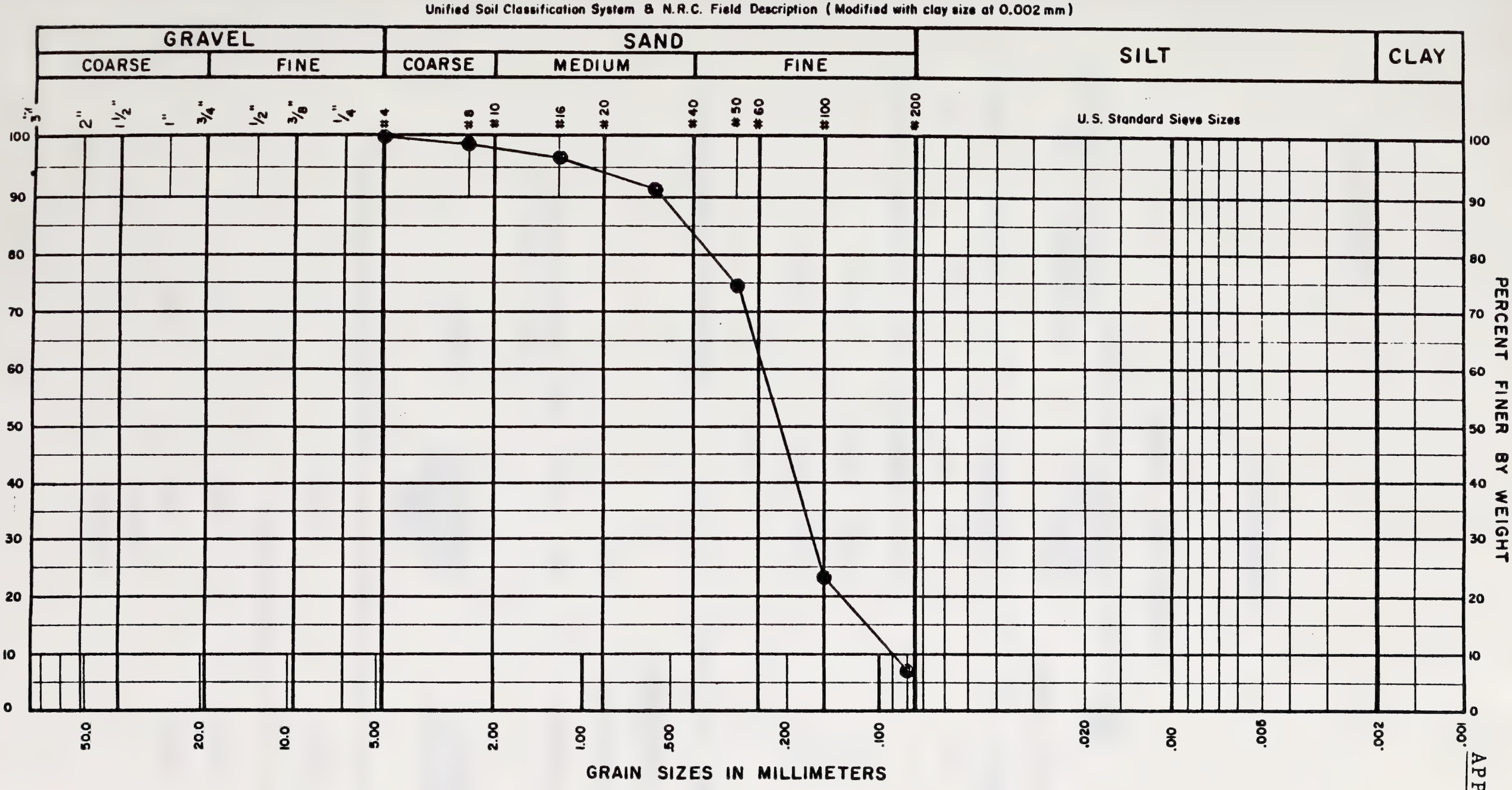
Average Asphalt Content = 7.0%

TOWN OF ST. ALBERT

GRADATION OF FOAMED ASPHALT MATERIAL FROM CORES

SIEVE SIZE	CORE NO. (21)	(27)	(29)	(31)	(51)	(AVERAGE)
	% PASSING					
5 mm				100	100	100
2.5 mm	100	100	100	98.4	98.6	99.4
1.25 mm	99.9	97.5	98.5	93.8	96.1	97.2
630 um	98.6	92.6	95.7	91.3	84.8	92.6
315 um	70.4	80.7	85.0	82.0	57.4	75.1
160 um	21.4	24.5	24.3	22.8	25.7	23.7
80 um	7.0	7.4	7.9	5.9	7.5	7.1

APPENDIX I-5



TOWN OF ST. ALBERT

Average Gradation of Foamed Asphalt Material from Cores.

			%
Nat. Water Content			
Liquid Limit			
Plastic Limit			
Plastic Index			

			%
Clay			
Silt			
Sand			
Gravel			

Classification

CLIENT

PROJECT

LOCATION

SAMPLE

TEST DATE FILE Nº

Geotechnical Engineers

APPENDIX 1

TOWN OF ST. ALBERT

1962 FOAMED ASPHALT MIX DESIGN

1. GRADATION OF SAND

SIEVE SIZE	% PASSING
#20	100
#40	98.9
#60	70.6
#100	31.2
#200	7.5

Plasticity index of sand - material non-plastic

2. MARSHALL SPECIMENS

Moisture content - 6%

Asphalt content - 6% (150 - 200 penetration grade asphalt)

SPECIMEN NO	DENSITIY lbs/cu.ft.	MARSHALL STABILITY (lbs)	FLOW
(Cured 3 days at 77°F & Immersed at 140°F for 20 Minutes)			
1	119.0	337.5	5
(Cured 3 days @ 77°F & broken dry)			
2	118.5	1465	7
3	120.0	1710	8

SPECIMEN NO	DENSITY lbs/cu.ft.	MARSHALL STABILITY (lbs)	FLOW
(Cured 3 days at 120°F & Immersed at 140°F for 20 minutes)			
4	117.0	952	13
(Cured 3 days at 120°F & broken dry)			
5	117.8	2720	6
6	115.0	2540	8

APPENDIX 2

SITE INVESTIGATIONS AND FOAMED ASPHALT MIX DESIGNS

APPENDIX 2

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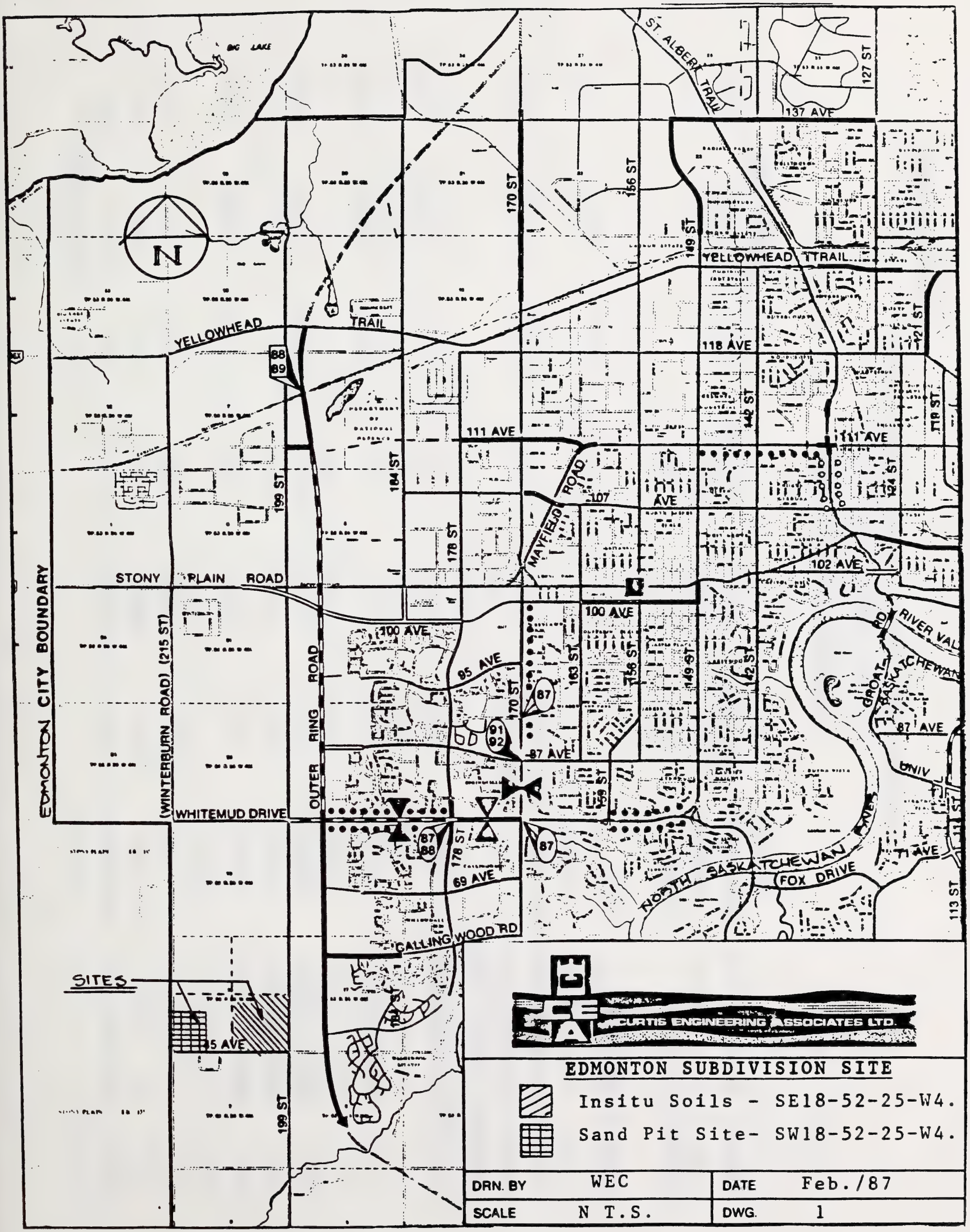


CURTIS ENGINEERING ASSOCIATES LTD.

EDMONTON SUBDIVISION SITE

▨ Insitu Soils - SE18-52-25-W4.

▦ Sand Pit Site- SW18-52-25-W4.

DRN. BY	WEC	DATE	Feb./87
SCALE	N T.S.	DWG.	1

APPENDIX 2-2

EDMONTON SUBDIVISION SITE, INSITU SOILS

(S.E. 18 - 52 - 25 - W4M)

LABORATORY TESTS DATA

SAMPLE NO.	DESCRIPTION OF SOILS	INSITU MOISTURE CONTENT (%)	LIQUID LIMIT (%)	PLASTIC LIMIT (%)	PLASTIC INDEX (%)	GRADATION		
						CLAY (%)	SILT (%)	SAND (%)
1	Silty Clay	17.5				62.0	31.0	7.0
2	Silty Clay	20.5						
3	Silty Clay	12.7	37.3	20.3	17.0	25.0	67.0	12.0
4	Silty Sand	8.2		Non Plastic				
5	Clayey Silt	6.7	26.5	19.8	6.7	18.0	42.0	40.0
6	Clayey Silt	4.8	29.5	19.4	10.1			
7	Silty Clay	12.0				44.0	48.0	8.0
8	Silty Clay	19.3	56.5	21.6	34.9			
9	Silty Clay	10.3				51.5	41.5	7.0
10	Silty Clay	13.0						
11	Silty Clay	14.0	34.5	22.2	12.3	43.0	39.0	18.0
12	Silty Clay	20.1						
13	Clayey Silt	6.8	27.3	21.4	5.9	18.0	58.5	23.5

SAMPLE NO.	DESCRIPTION OF SOILS	INSITU MOISTURE CONTENT (%)	LIQUID LIMIT (%)	PLASTIC LIMIT (%)	PLASTIC INDEX (%)	GRADATION		
						CLAY (%)	SILT (%)	SAND (%)
14	Clayey Silt	7.0						
15	Silty Clay	11.1	56.7	26.5	30.2			
16	Silty Clay	11.8	55.0	23.0	32.0	51.0	39.0	10.0
	AVERAGE:	12.2	40.4	21.8	16.6	39.1	45.8	15.7

TEST DATA ON SAMPLE OF MATERIAL

STANDARD PROCTOR DATA:

Maximum Dry Unit Weight = 1893 kg/m^3
Optimum Moisture Content = 15.0 %

SPECIFIC GRAVITY: 2.73

ABSORPTION: 0.6%

APPENDIX 2-3

FOAMED ASPHALT MIX DESIGN DATA
EDMONTON INSITU SOILS

TEST SERIES 3-A

Asphalt Grade: 150 - 200 penetration
Asphalt Content: 5% (by dry weight)
Moisture Content: 90% optimum = 13.5%
Curing Temperature: 60°C (140°F)

SPECIMEN NO.	DENSITY (kg/m^3)	LENGTH OF CURE	BREAK CONDITIONS	FLOW (0.25 mm)	STABILITY (N)*	AVERAGE (N)
3-A1	1910	3 days	Dry	16.4	36,400	
3-A2	1904	" "	"	15.9	40,800	38,600 (8674 lbs)
3-A3	1885	3 days	Wet **	4.0	576	
3-A4	1906	" "	"	4.0	659	
3-A5	1898	" "	"	4.0	728	655 (147 lbs)

*N = Newtons

** Tested after 30 Min. immersion at 60°C (140°F)

SPECIMEN NO.	DENSITY (kg/m³)	LENGTH OF CURE	BREAK CONDITIONS	FLOW (0.25 mm)	STABILITY (N)*	AVERAGE (N)
3-A6	1881	7 days	Dry	14.8	44,550	
3-A7	1890	" "	"	14.0	43,997	44,273
						(9949 lbs)
3-A8	1770	7 days	Wet **	4.0	1,201	
3-A9	1886	" "	"	4.0	1,672	1,436
						(323 lbs)

*N = Newtons

** Tested after 30 Min. immersion at 60° (140°F)

FOAMED ASPHALT MIX DESIGN DATA

EDMONTON INSITU SOILS

TEST SERIES 3-B

Asphalt Grade: 150 - 200 penetration
Asphalt Content: 6% (by dry weight)
Moisture Content: 90% optimum = 13.5%
Curing Temperature: 60°C (140°F)

SPECIMEN NO.	DENSITY (kg/m^3)	LENGTH OF CURE	BREAK CONDITIONS	FLOW (0.25 mm)	STABILITY (N)*	AVERAGE (N)
3-B1	1912	3 days	Dry	16.0	31,800	
3-B2	1921	" "	"	15.3	32,000	37,400
						(8404 lbs)
3-B3	1929	3 days	Wet **	4.0	961	
3-B4	1926	" "	"	4.0	480	
3-B5	1917	" "	"	6.0	1,201	881
						(198 lbs)

*N = Newtons

** Tested after 30 Min. immersion at 60°C (140°F)

SPECIMEN NO.	DENSITY (kg/m^3)	LENGTH OF CURE	BREAK CONDITIONS	FLOW (0.25 mm)	STABILITY (N)*	AVERAGE (N)
3-B6	1896	7 days	Dry	16.0	43,000	
3-B7	1884	" "	"	15.6	39,000	41,000 (9213 lbs)
3-B8	1901	7 days	Wet **	2.0	961	
3-B9	1888	" "	"	4.0	1,672	1,317 (296 lbs)

*N = Newtons

** Tested after 30 Min. immersion at 60°C (140°F)

FOAMED ASPHALT MIX DESIGN DATA
EDMONTON INSITU SOILS

TEST SERIES 3-C

Asphalt Grade: 150 - 200 penetration
Asphalt Content: 7% (by dry weight)
Moisture Content: 90% optimum = 13.5%
Curing Temperature: 60°C (140°F)

SPECIMEN NO.	DENSITY	LENGTH OF CURE	BREAK CONDITIONS	FLOW	STABILITY	AVERAGE
	(kg/m^3)			(0.25 mm)	(N)*	(N)
3-C1	1884	3 days	Dry	16.5	31,060	
3-C2	1875	" "	"	15.3	30,175	30,622 (6881 lbs)
3-C3	1883	3 days	Wet **	4.0	1,201	
3-C4	1896	" "	"	4.2	721	
3-C5	1902	" "	"	4.4	1,437	1,120 (252 lbs)

* = Newtons

** Tested after 30 Min. immersion at 60°C (140°F)

SPECIMEN NO.	DENSITY (kg/m^3)	LENGTH OF CURE	BREAK CONDITIONS	FLOW (0.25 mm)	STABILITY (N)*	AVERAGE (N)
3-C6	1898	7 days	Dry	18.0	43,208	
3-C7	1873	" "	"	16.4	39,004	41,106 (9237 lbs)
3-C8	1879	7 days	Wet **	4.0	1,579	
3-C9	1877	" "	"	4.0	1,913	1,746 (392 lbs)

*N = Newtons

** Tested after 30 Min. immersion at 60°C (140°F)

APPENDIX 2-3

FOAMED ASPHALT MIX DESIGN DATA

EDMONTON INSITU SOILS

TEST SERIES: 3-D

Asphalt Grade: 150 - 200 penetration
Asphalt Content: 6.5% (by dry weight)
Moisture Content: 90% optimum = 13.5%
Curing Temperature: 60°C (140°F)

SPECIMEN NO.	DENSITY	LENGTH OF CURE	BREAK CONDITIONS	FLOW	STABILITY	AVERAGE
	(kg/m³)			(0.25 mm)	(N)*	(N)
3-D1	1789	3 days	Dry	16.0	29,730	
3-D2	1771	" "	"	16.0	27,942	28,836
						(6480 lbs)
3-D3	1786	3 days	Wet **	12.0	8,442	
3-D4	1781	" "	"	13.2	8,673	
3-D5	1788	" "	"	13.4	7,517	8,211
						(1845 lbs)

*N = Newtons

** Tested after 30 Min. immersion at 60°C (140°F)

SPECIMEN NO.	DENSITY (kg/m^3)	LENGTH OF CURE	BREAK CONDITIONS	FLOW (0.25 mm)	STABILITY (N)*	AVERAGE (N)
3-D6	1786	7 days	Dry ***	11.2	14,842	
3-D7	1786	" "	"	12.8	14,438	14,640 (3290 lbs)
3-D8	1770	7 days	Wet *** **	4.0	4,034	
3-D9	1784	" "	"	4.8	4,265	4,150 (933 lbs)

*N = Newtons

** Tested after 30 Min. immersion at 60°C (140°F)

*** Specimens subjected to 6 cycles of freeze-thaw.

APPENDIX 2-4

FOAMED ASPHALT MIX DESIGN DATA

TYPICAL EDMONTON SAND

TEST SERIES 4-A

Asphalt Grade: 150 - 200 penetration
Asphalt Content: 4.5% (by dry weight)
Moisture Content: 90% optimum = 9.0%
Curing Temperature: 60°C (140°F)

SPECIMEN NO.	DENSITY (kg/m^3)	LENGTH OF CURE	BREAK CONDITIONS	FLOW (0.25 mm)	STABILITY (N)*	AVERAGE (N)
4-A1	1751	3 days	Dry	17.0	13,000	
4-A2	1765	" "	"	16.0	14,100	13,550
						(3045 lbs)
4-A3	1742	3 days	Wet **	4.0	1,676	
4-A4	1742	" "	"	4.0	1,676	
4-A5	1753	" "	"	4.0	1,913	1,755
						(394 lbs)

*N = Newtons

** Tested after 30 Min. immersion at 60°C (140°F)

SPECIMEN NO.	DENSITY	LENGTH OF CURE	BREAK CONDITIONS	FLOW	STABILITY	AVERAGE
	(kg/m^3)			(0.25 mm)	(N)*	(N)
4-A6	1763	7 days	Dry	12.6	17,200	
4-A7	1745	" "	"	12.0	16,200	16,700 (3750 lbs)
4-A8	1745	7 days	Wet **	2.0	1,680	
4-A9	1751	" "	*	2.2	2,000	1,840 (413 lbs)

*N = Newtons

** Tested after 30 Min. immersion at 60°C (140°F)

APPENDIX 2-4

FOAMED ASPHALT MIX DESIGN DATA
TYPICAL EDMONTON SAND

TEST SERIES 4-B

Asphalt Grade: 150 - 200 penetration
Asphalt Content: 5.5% (by dry weight)
Moisture Content: 90% optimum = 9.0%
Curing Temperature: 60°C (140°F)

SPECIMEN NO.	DENSITY	LENGTH OF CURE	BREAK CONDITIONS	FLOW	STABILITY	AVERAGE
	(kg/m^3)			(0.25 mm)	(N)*	(N)
4-B1	1755	3 days	Dry	15.5	16,860	
4-B2	1750	" "	"	15.0	13,930	15,400 (3460 lbs)
4-B3	1751	3 days	Wet **	1.5	1,670	
4-B4	1748	" "	"	4.0	1,913	
4-B5	1746	" "	"	4.5	1,915	1,833 (412 lbs)

*N = Newtons

** Tested after 30 Min. immersion at 60°C (140°F)

SPECIMEN NO.	DENSITY (kg/m^3)	LENGTH OF CURE	BREAK CONDITIONS	FLOW (0.25 mm)	STABILITY (N)*	AVERAGE (N)
4-B6	1762	7 days	Dry	16.0	14,840	
4-B7	1759	" "	"	10.8	15,540	15,190 (3413 lbs)
4-B8	1743	7 days	Wet **	7.2	1,630	
4-B9	1745	" "	"	6.0	2,000	1,815 (408 lbs)

*N = Newtons

** Tested after 30 Min. immersion at 60°C (140°F)

FOAMED ASPHALT MIX DESIGN DATA
TYPICAL EDMONTON SAND

TEST SERIES 4-C

Asphalt Grade: 150 - 200 penetration
Asphalt Content: 6.5% (by dry weight)
Moisture Content: 90% optimum = 9.0%
Curing Temperature: 60°C (140°F)

SPECIMEN NO.	DENSITY (kg/m³)	LENGTH OF CURE	BREAK CONDITIONS	FLOW (0.25 mm)	STABILITY (N)*	AVERAGE (N)
4-C2	1767	3 days	Dry	14.5	18,000	
4-C2	1768	" "	"	15.0	18,400	18,200 (4090 lbs)
4-C3	1767	3 days	Wet **	6.0	2,384	
4-C4	1757	" "	"	4.0	1,913	
4-C5	1764	" "	"	6.0	1,676	1,991 (447 lbs)

* = Newtons
** Tested after 30 Min. immersion at 60°C (140°F)

SPECIMEN NO.	DENSITY (kg/m³)	LENGTH OF CURE	BREAK CONDITIONS	FLOW (0.25 mm)	STABILITY (N)*	AVERAGE (N)
4-C6	1775	7 days	Dry	14.8	23,445	
4-C7	1766	" "	"	14.9	22,542	22,993 (5167 lbs)
4-C8	1768	7 days	Wet **	4.0	961	
4-C9	1763	" "	"	4.0	1,437	1,199 (269 lbs)

*N = Newtons

** Tested after 30 Min. immersion at 60°C (140°F)

APPENDIX 2-4

FOAMED ASPHALT MIX DESIGN

TYPICAL EDMONTON SAND WITH 15% EDMONTON INSITU SOIL ADDED

TEST SERIES 4-D

Asphalt Grade: 150 - 200 penetration
Asphalt Content: 5.7% (by dry weight)
Moisture Content: 90% optimum = 7.6%
Curing Temperature: 60°C (140°F)

SPECIMEN NO.	DENSITY	LENGTH OF CURE	BREAK CONDITIONS	FLOW	STABILITY	AVERAGE
	(kg/m^3)			(0.25 mm)	(N)*	(N)
4-D1	1863	3 days	Dry	16.4	14,843	
4-D2	1860	" "	"	17.2	16,234	15,538 (3492 lbs)
4-D3	1854	3 days	Wet **	14.4	5,738	
4-D4	1855	" "	"	15.6	5,871	
4-D5	1869	" "	"	15.2	5,822	5,810 (1306 lbs)

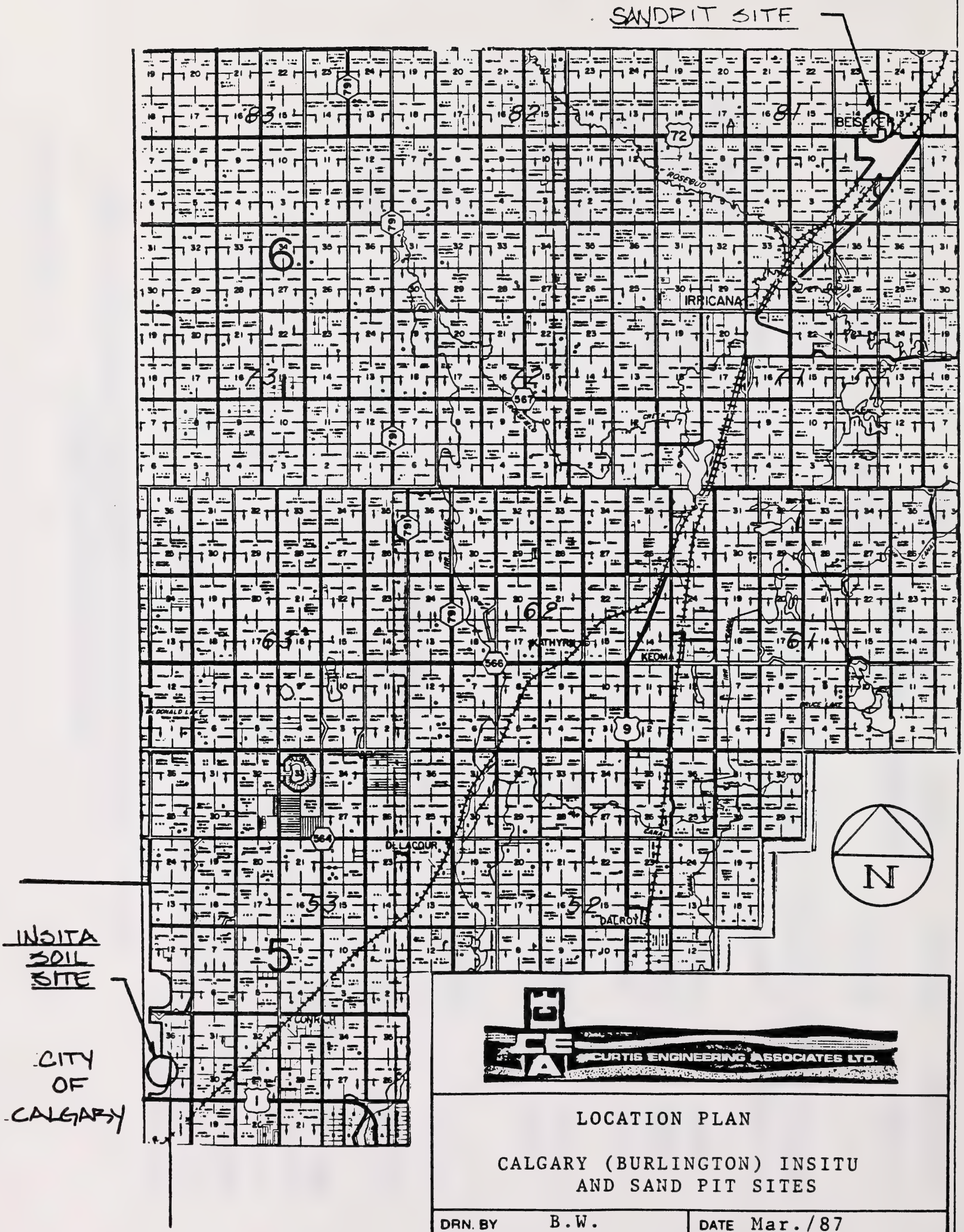
*N = Newtons

** Tested after 30 Min. immersion at 60°C (140°F)

SPECIMEN NO.	DENSITY (kg/m^3)	LENGTH OF CURE	BREAK CONDITIONS	FLOW (0.25 mm)	STABILITY (N)*	AVERAGE (N)
4-D6	1871	7 days	Dry ***	15.6	15,305	
4-D7	1865	" "	"	17.2	16,506	15,905
						(3574 lbs)
4-D8	1869	7 days	Dry ***	17.6	16,235	
4-D9	1873	" "	"	16.0	16,164	16,199
						(3640 lbs)

*N = Newtons

*** Specimens subjected to 6 cycles of freeze-thaw.



CURTIS ENGINEERING ASSOCIATES LTD.

LOCATION PLAN

CALGARY (BURLINGTON) INSITU AND SAND PIT SITES

DRN. BY	B.W.	DATE	Mar./87
SCALE	N.T.S.	DWG.	2

APPENDIX 2-6

CALGARY BURLINGTON SUBDIVISION SITE

INSITU SOILS

LABORATORY TESTS DATA

					GRADATION		
SAMPLE NO.	DESCRIPTION OF SOILS	LIQUID LIMIT (%)	PLASTIC LIMIT (%)	PLASTIC INDEX (%)	CLAY (%)	SILT (%)	SAND (%)
1	Silty Clay	28.3	7.3	21.0	29.5	42.5	28.0
2	Silty Clay	31.5	8.8	22.7	32.0	43.0	25.0
3	Silty Clay	25.2	19.4	5.8	29.5	46.5	24.0
4	Silty Clay	36.8	12.6	24.2	32.0	44.5	23.5
5	Silty Clay	34.2	17.4	16.8	30.0	47.0	23.0
6	Silty Clay	29.2	15.4	13.8	32.0	45.0	23.0
7	Silty Clay	32.8	17.0	15.8	32.0	40.0	28.0
8	Silty Clay	29.8	15.9	13.9	29.0	41.0	30.0
	AVERAGE:	30.9	14.2	16.8	30.7	43.7	25.6

STANDARD PROCTOR DATA:

Maximum Dry Unit Weight = 1750 kg/m^3

Optimum Moisture Conent = 17.5 %

SPECIFIC GRAVITY: 2.71

ABSORPTION: 0.3%

APPENDIX 2-7

CALGARY (BURLINGTON) INSITU SOIL
MIX DESIGN DATA

TEST SERIES: 7-A

Asphalt Grade: 150 - 200 penetration
Asphalt Content: 4.5% (by dry weight)
Moisture Content: 90% optimum = 15.7%
Curing Temperature: 60°C (140°F)

SPECIMEN NO.	DENSITY	LENGTH OF CURE	BREAK CONDITIONS	FLOW	STABILITY	AVERAGE
	(kg/m^3)			(0.25 mm)	(N)*	(N)
7-A1	1905	3 days	Dry	16.0	30.620	
7-A2	1907	" "	"	12.0	26,320	28,470
						(6398 lbs)
7-A3	1915	3 days	Wet **	4.0	5,666	
7-A4	1913	" "	"	3.8	4,265	
7-A5	1913	" "	"	4.3	5,199	5,043
						(1,133 lbs)

*N = Newtons

** Tested after 30 Min. immersion at 60°C (140°F)

SPECIMEN NO.	DENSITY (kg/m^3)	LENGTH OF CURE	BREAK CONDITIONS	FLOW (0.25 mm)	STABILITY (N)*	AVERAGE (N)
7-A6	1879	7 days	Dry	12.0	34,180	
7-A7	1870	" "	"	11.5	34,400	34,290 (7705 lbs)
7-A8	1858	7 days	Wet **	8.0	9,363	
7-A9	1861	" "	"	6.0	7,054	8,208 (1845 lbs)

*N = Newtons

** Tested after 30 Min. immersion at 60°C (140°F)

APPENDIX 2-7

CALGARY (BURLINGTON) INSITU SOIL
MIX DESIGN DATA

TEST SERIES 7-B

Asphalt Grade: 150 - 200 penetration
Asphalt Content: 5.5% (by dry weight)
Moisture Content: 90% optimum = 15.7%
Curing Temperature: 60°C (140°F)

SPECIMEN NO.	DENSITY (kg/m^3)	LENGTH OF CURE	BREAK CONDITIONS	FLOW (0.25 mm)	STABILITY (N)*	AVERAGE (N)
7-B1	1896	3 days	Dry	15.6	26,145	
7-B2	1905	" "	"	15.2	27,448	26,796
						(6022 lbs)
7-B3	1911	3 days	Wet **	8.0	5,666	
7-B4	1898	" "	"	8.1	5,942	
7-B5	1900	" "	"	8.0	4,772	5,460
						(1227 lbs)

*N = Newtons

** Tested after 30 Min. immersion at 60°C (140°F)

SPECIMEN NO.	DENSITY	LENGTH OF CURE	BREAK CONDITIONS	FLOW	STABILITY	AVERAGE
	(kg/m^3)			(0.25 mm)	(N)*	(N)
7-B6	1878	7 days	Dry	12.0	35,068	
7-B7	1784	" "	"	14.0	34,152	34,610 (7777 lbs)
7-B8	1834	7 days	Wet **	12.0	7,979	
7-B9	1833	" "	"	11.6	7,054	7,516 (1698 lbs)

*N = Newtons

** Tested after 30 Min. immersion at 60°C (140°F)

APPENDIX 2-7

CALGARY (BURLINGTON) INSITU SOIL
MIX DESIGN DATA

TEST SERIES 7-C

Asphalt Grade: 150 - 200 penetration
Asphalt Content: 6.5% (by dry weight)
Moisture Content: 90% optimum = 15.7%
Curing Temperature: 60°C (140°F)

SPECIMEN NO.	DENSITY (kg/m^3)	LENGTH OF CURE	BREAK CONDITIONS	FLOW (0.25 mm)	STABILITY (N)*	AVERAGE (N)
7-C1	1886	3 days	Dry	16.0	22,540	
7-C2	1902	" "	"	15.3	21,190	22,365 (5026 lbs)
7-C3	1891	3 days	Wet **	4.0	2,165	
7-C4	1884	" "	"	6.0	5,199	
7-C5	1896	" "	"	6.0	4,968	4,111 (924 lbs)

* = Newtons

** Tested after 30 Min. immersion at 60°C (140°F)

SPECIMEN NO.	DENSITY (kg/m^3)	LENGTH OF CURE	BREAK CONDITIONS	FLOW (0.25 mm)	STABILITY (N)*	AVERAGE (N)
7-C6	1858	7 days	Dry	16.3	30,175	
7-C7	1866	" "	"	18.8	28,387	29,280 (6580 lbs)
7-C8	1859	7 days	Wet **	11.0	8,393	
7-C9	1848	" "	"	11.7	7,979	8,186 (1840 lbs)

*N = Newtons

** Tested after 30 Min. immersion at 60°C (140°F)

APPENDIX 2-7

CALGARY (BURLINGTON) INSITU SOIL
MIX DESIGN DATA

TEST SERIES 7-D

Asphalt Grade: 150 - 200 penetration
Asphalt Content: 6.0% (by dry weight)
Moisture Content: 90% optimum = 15.7%
Curing Temperature: 60°C (140°F)

SPECIMEN NO.	DENSITY (kg/m^3)	LENGTH OF CURE	BREAK CONDITIONS	FLOW (0.25 mm)	STABILITY (N)*	AVERAGE (N)
7-D1	1867	3 days	Dry	16.4	25,833	
7-D2	1860	" "	"	17.6	25,976	25,833 (5805 lbs)
7-D3	1855	3 days	Wet **	7.6	6,271	
7-D4	1874	" "	"	8.4	6,352	
7-D5	1877	" "	"	6.8	6,213	6,279 (1410 lbs)

*N = Newtons

** Tested after 30 Min. immersion at 60°C (140°F)

SPECIMEN NO.	DENSITY (kg/m^3)	LENGTH OF CURE	BREAK CONDITIONS	FLOW (0.25 mm)	STABILITY (N)*	AVERAGE (N)
7-D6	1869	7 days	Dry ***	15.2	25,647	
7-D7	1859	" "	"	14.0	25,353	25,500 (5730 lbs)
7-D8	1877	7 days	Dry ***	13.6	25,318	
7-D9	1871	" "	"	15.2	25,378	25,348 (5696 lbs)

*N = Newtons

*** Specimens subjected to 6 cycles of freeze-thaw.

APPENDIX 2-8

TYPICAL CALGARY AREA FINE SANDS
MIX DESIGN DATA

TEST SERIES 8-A

Asphalt Grade: 150 - 200 penetration
Asphalt Content: 4.5% (by dry weight)
Moisture Content: 90% optimum = 11.9%
Curing Temperature: 60°C (140°F)

SPECIMEN NO.	DENSITY (kg/m^3)	LENGTH OF CURE	BREAK CONDITIONS	FLOW (0.25 mm)	STABILITY (N)*	AVERAGE (N)
8-A1	1742	3 days	Dry	16.0	17,100	
8-A2	1754	" "	"	15.2	16,026	16,560 (3722 lbs)
8-A3	1773	3 days	Wet **	--	Failed	
8-A4	1746	" "	"	--	"	
8-A5	1771	" "	"	--	"	

*N = Newtons
** Tested after 30 Min. immersion at 60°C (140°F)

SPECIMEN NO.	DENSITY (kg/m^3)	LENGTH OF CURE	BREAK CONDITIONS	FLOW (0.25 mm)	STABILITY (N)*	AVERAGE (N)
8-A6	1762	7 days	Dry	18.0	14,390	
8-A7	1734	" "	"	16.0	14,010	14,200 (3190 lbs)
8-A8	1740	7 days	Wet **	--	Failed	
8-A9	1738	" "	"	--	"	

*N = Newtons

** Tested after 30 Min. immersion at 60°C (140°F)

APPENDIX 2-8

TYPICAL CALGARY AREA FINE SANDS

MIX DESIGN DATA

TEST SERIES 8-B

Asphalt Grade: 150 - 200 penetration
Asphalt Content: 5.5% (by dry weight)
Moisture Content: 90% optimum = 11.9%
Curing Temperature: 60°C (140°F)

SPECIMEN NO.	DENSITY	LENGTH OF CURE	BREAK CONDITIONS	FLOW	STABILITY	AVERAGE
	(kg/m^3)			(0.25 mm)	(N)*	(N)
8-B1	1744	3 days	Dry	14.8	22,090	
8-B2	1734	" "	"	14.0	18,470	20,280 (4557 lbs)
8-B3	1728	3 days	Wet **	--	Failed	
8-B4	1719	" "	"	--	"	
8-B5	1720	" "	"	--	"	

* = Newtons

** Tested after 30 Min. immersion at 60°C (140°F)

SPECIMEN NO.	DENSITY (kg/m^3)	LENGTH OF CURE	BREAK CONDITIONS	FLOW (0.25 mm)	STABILITY (N)*	AVERAGE (N)
8-B6	1739	7 days	Dry	10.8	22,540	
8-B7	1719	" "	"	9.6	21,190	21,865 (4913 lbs)
8-B8	1718	7 days	Wet **	--	Failed	
8-B9	1712	" "	"	--	"	

*N = Newtons

** Tested after 30 Min. immersion at 60°C (140°F)

APPENDIX 2-8

TYPICAL CALGARY AREA FINE SANDS

MIX DESIGN DATA

TEST SERIES: 8-C

Asphalt Grade: 150 - 200 penetration
Asphalt Content: 6.5% (by dry weight)
Moisture Content: 90% optimum = 11.9%
Curing Temperature: 60°C (140°F)

SPECIMEN NO.	DENSITY (kg/m^3)	LENGTH OF CURE	BREAK CONDITIONS	FLOW (0.25 mm)	STABILITY (N)*	AVERAGE (N)
8-C1	1769	3 days	Dry	15.6	19,380	
8-C2	1754	" "	"	16.8	22,040	20,710 (4654 lbs)
8-C3	1735	3 days	Wet	--	--	
8-C4	1748	" "	"	--	--	
8-C5	1751	" "	"	--	--	

*N = Newtons

SPECIMEN NO.	DENSITY (kg/m^3)	LENGTH OF CURE	BREAK CONDITIONS	FLOW (0.25 mm)	STABILITY (N)*	AVERAGE (N)
8-C6	1739	7 days	Dry	18.1	18,020	
8-C7	1740	" "	"	19.2	19,830	18,925 (4253 lbs)
8-C8	1736	7 days	Wet **	4.0	1,912	
8-C9	1734	" "	"	4.0	1,437	1,675 (419 lbs)

*N = Newtons

** Tested after 30 Min. immersion at 60°C (140°F)

APPENDIX 2-8

TYPICAL CALGARY AREA FINE SANDS
WITH 10% CALGARY INSITU CLAY SOIL ADDED
MIX DESIGN DATA

TEST SERIES: 8-D

Asphalt Grade: 150 - 200 penetration
Asphalt Content: 6.0% (by dry weight)
Moisture Content: 90% optimum = 11.9%
Curing Temperature: 60°C (140°F)

SPECIMEN NO.	DENSITY (kg/m^3)	LENGTH OF CURE	BREAK CONDITIONS	FLOW (0.25 mm)	STABILITY (N)*	AVERAGE (N)
8-D1	1864	3 days	Dry	12.8	29,730	
8-D2	1856	" "	"	10.4	27,942	28,836 (6480 lbs)
8-D3	1850	3 days	Wet **	8.0	7,517	
8-D4	1850	" "	"	6.4	7,059	
8-D5	1846	" "	"	4.4	5,667	6,748 (1516 lbs)

*N = Newtons
** Tested after 30 Min. immersion at 60°C (140°F)

SPECIMEN NO.	DENSITY (kg/m^3)	LENGTH OF CURE	BREAK CONDITIONS	FLOW (0.25 mm)	STABILITY (N)*	AVERAGE (N)
8-D6	1845	7 days	Dry ***	13.2	21,639	
8-D7	1843	" "	"	12.4	16,341	18,990 (4267 lbs)
8-D8	1870	7 days	Wet *** **	5.6	6,129	
8-D9	1838	" "	"	6.0	5,431	5,780 (1299 lbs)

*N = Newtons

** Tested after 30 Min. immersion at 60°C (140°F)

*** Specimens subjected to 6 cycles of freeze-thaw.

N.L.C. - B.N.C.
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